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(54) **LASER BEAM IRRADIATION APPARATUS AND METHOD OF MANUFACTURING ORGANIC LIGHT-EMITTING DISPLAY DEVICE BY USING THE SAME**

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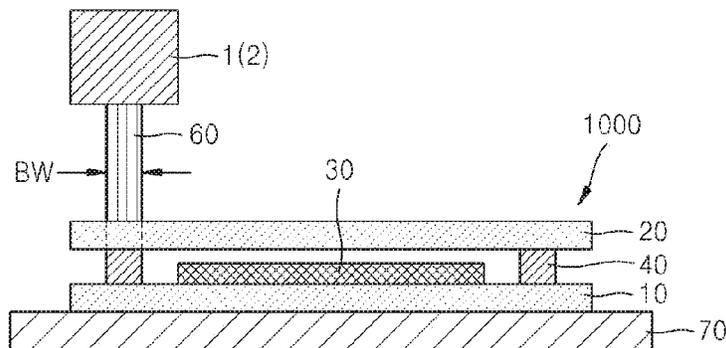
(56) **References Cited**
U.S. PATENT DOCUMENTS
5,465,243 A * 11/1995 Boardman G02B 26/108 369/112.28
8,226,448 B2 7/2012 Voronov et al.
(Continued)

FOREIGN PATENT DOCUMENTS
CN 102185114 9/2011
JP 2005-140588 6/2005
(Continued)

OTHER PUBLICATIONS
Extended European Search Report dated Oct. 8, 2014, in European Patent Application No. 14162974.1.
(Continued)

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(57) **ABSTRACT**
A laser beam irradiation apparatus including a laser source configured to emit light; a collimator configured to collimate the emitted light; a scanner configured to adjust the collimated light to change an irradiation direction thereof; a first lens part configured to focus the adjusted light to irradiate a laser beam on a sealing part; a camera configured to receive visible light passing through the scanner; a heat sensing part configured to receive infrared (IR) light passing through the
(Continued)



scanner; and a control part configured to control a moving direction and an intensity of the laser beam.

8 Claims, 5 Drawing Sheets

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H01L 21/66 (2006.01)

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 See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

9,823,201 B2 *	11/2017	Morton	.....	G01V 5/0008
2006/0122502 A1 *	6/2006	Scherch	.....	A61B 6/0492
				600/426
2007/0045541 A1 *	3/2007	Urey	.....	G01J 5/38
				250/338.3
2007/0256088 A1 *	11/2007	Yamamoto	.....	G11B 7/0037
				720/601
2009/0086325 A1	4/2009	Liu et al.		
2009/0212316 A1	8/2009	Braune et al.		
2009/0216373 A1 *	8/2009	Berti	.....	G01N 23/2073
				700/258
2010/0109516 A1	5/2010	Warashina et al.		
2010/0118912 A1	5/2010	Lai et al.		

2010/0296291 A1	11/2010	Kang		
2011/0165814 A1	7/2011	Lee et al.		
2011/0177746 A1 *	7/2011	Voronov	.....	B23K 26/073
				445/25
2012/0287026 A1	11/2012	Masuda		
2013/0023076 A1	1/2013	Uchiyama		
2013/0334185 A1	12/2013	Nomaru		
2014/0029013 A1 *	1/2014	Yoshii	.....	G01B 9/02091
				356/479
2014/0174664 A1	6/2014	Lee		

FOREIGN PATENT DOCUMENTS

KR	10-2009-0128431	12/2009
KR	10-2011-0085135	7/2011
KR	10-2012-0033392	4/2012
KR	10-2014-0081509	7/2014

OTHER PUBLICATIONS

Non-Final Office Action dated Apr. 27, 2015, in U.S. Appl. No. 14/293,495.
 Final Office Action dated Nov. 19, 2015, in U.S. Appl. No. 14/293,495.
 Non-Final Office Action dated Mar. 11, 2016, in U.S. Appl. No. 14/293,495.
 Final Office Action dated Sep. 26, 2016, in U.S. Appl. No. 14/293,495.
 Non-Final Office Action dated Feb. 10, 2017, in U.S. Appl. No. 14/293,495.
 Final Office Action dated Oct. 12, 2017, in U.S. Appl. No. 14/293,495.
 Notice of Allowance dated Apr. 19, 2018, in U.S. Appl. No. 14/293,495.

* cited by examiner

FIG. 1

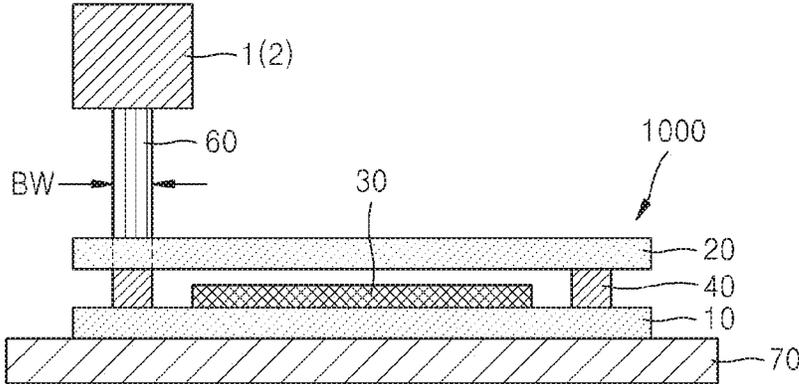


FIG. 2

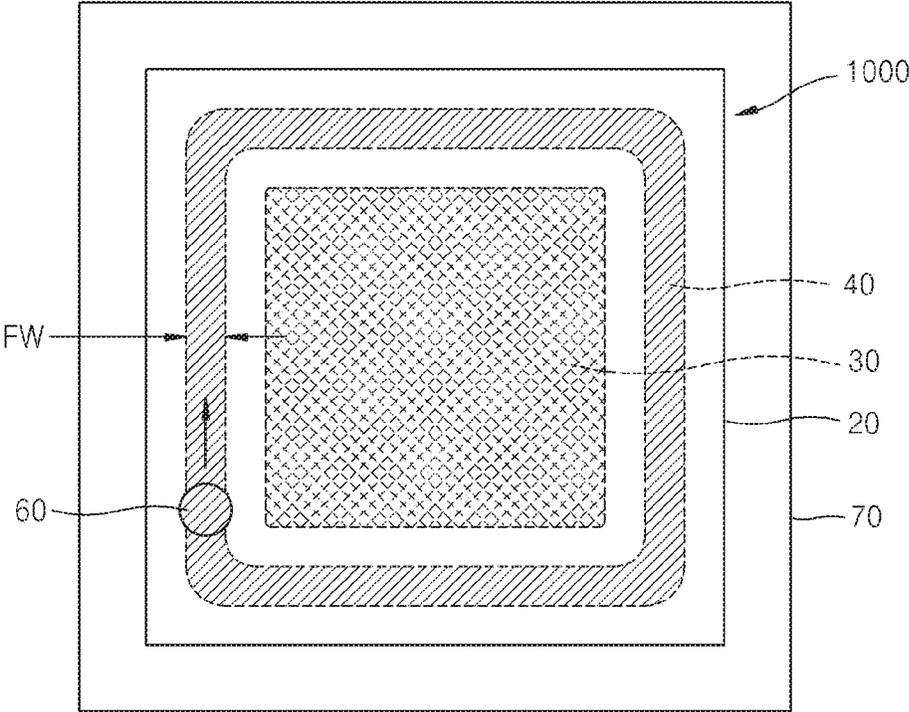


FIG. 3

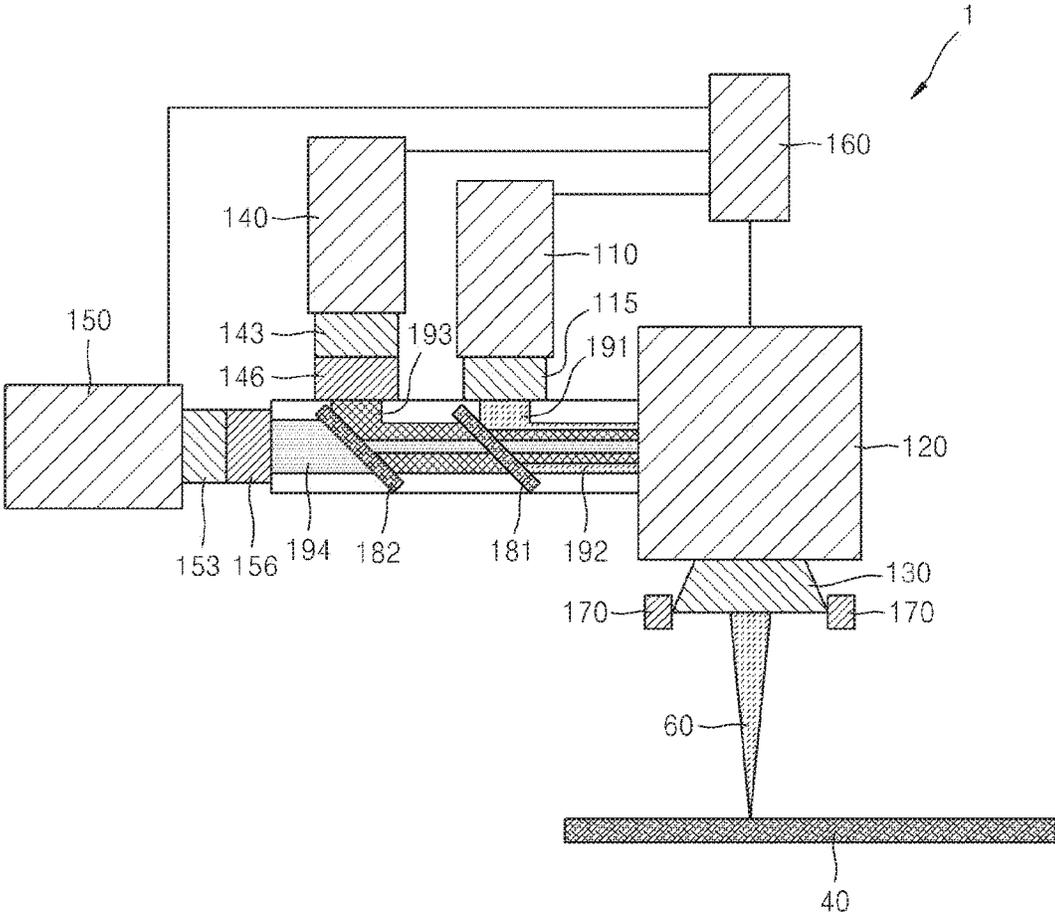


FIG. 4

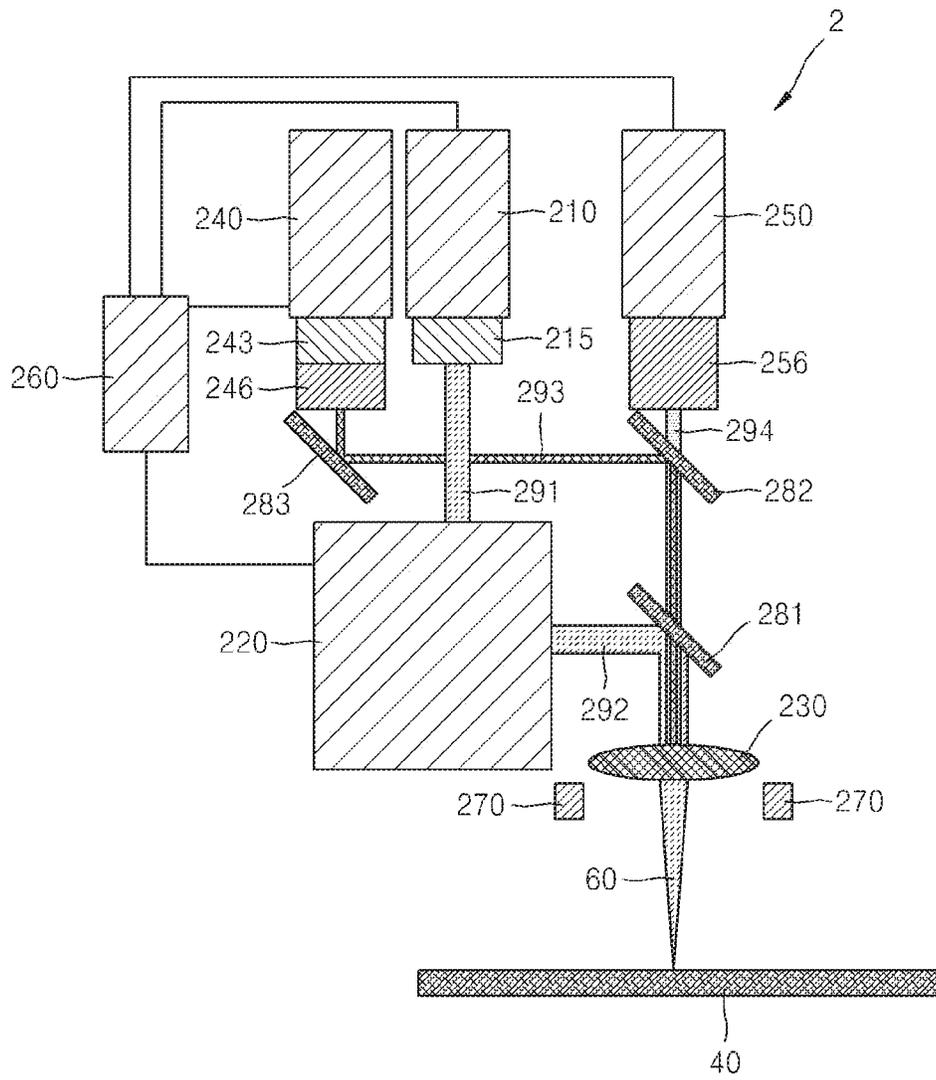


FIG. 5

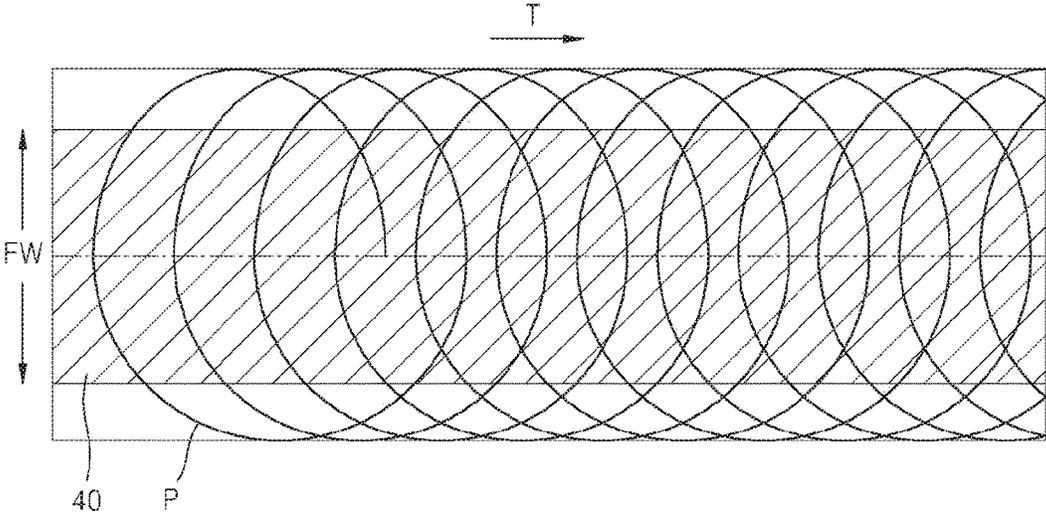


FIG. 6

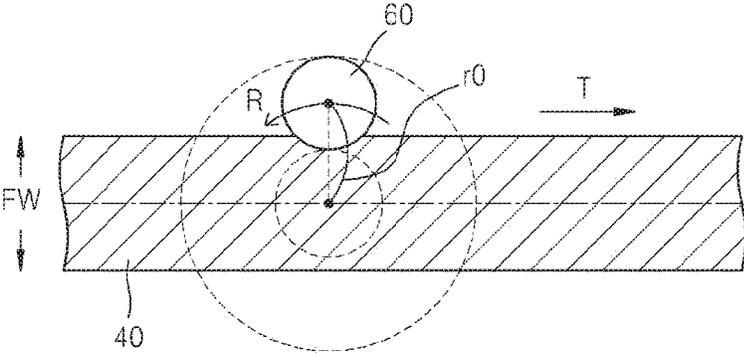
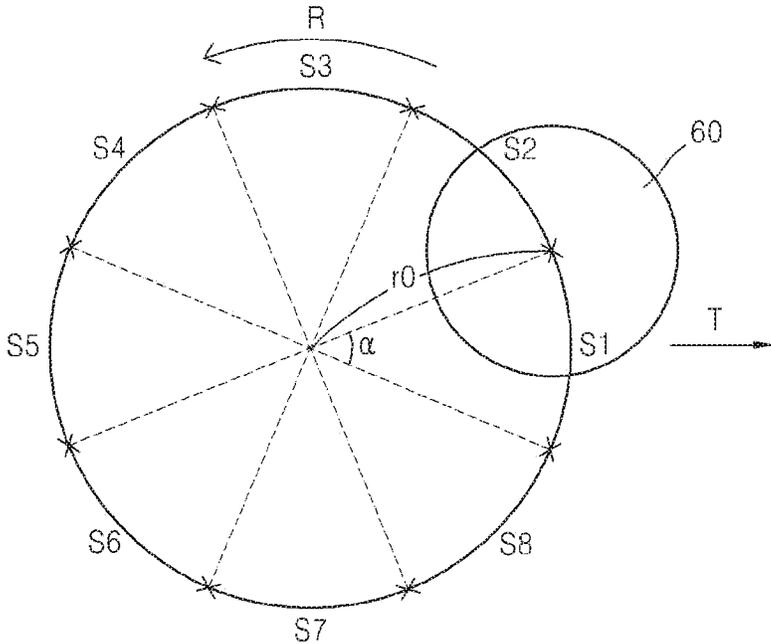


FIG. 7



**LASER BEAM IRRADIATION APPARATUS
AND METHOD OF MANUFACTURING
ORGANIC LIGHT-EMITTING DISPLAY
DEVICE BY USING THE SAME**

CROSS-REFERENCE TO RELATED
APPLICATION

This application is a Divisional of U.S. patent application Ser. No. 14/293,495, filed on Jun. 2, 2014, which claims priority from and the benefit of Korean Patent Application No. 10-2013-0063083, filed on May 31, 2013, both of which are hereby incorporated by reference for all purposes as if fully set forth herein.

BACKGROUND OF THE INVENTION

Field

The present disclosure relates to a laser beam irradiation apparatus used to seal a substrate and a method of manufacturing an organic light-emitting display device by using the same.

Discussion of the Background

In the recent times, portable and thin flat panel display devices have increasingly been used for the displays of electronic devices. Among the flat panel display devices, electroluminescence display devices are a self-emitting type of display device having characteristics such as wide viewing angles, good contrast, and fast response times and thus attract much attention as those of the next generation display devices. Also, the organic light-emitting display devices, of which the emitting layer is formed of organic materials, are known for better luminance, driving voltage, and response time characteristics than the inorganic light-emitting display devices and can realize multicolor emission.

Generally, the organic light-emitting display devices have configurations that one or more organic layers are arranged, including an emitting layer between a pair of electrodes.

As far as the organic light-emitting display devices are concerned, when moisture or oxygen penetrates from the ambient environment to the inside of a device, the electrode materials are likely oxidized and peeled off, and for this reason, the service life of the organic light-emitting device is shortened, the emission efficiency is degraded, and the emission color is degenerated.

Therefore, in manufacturing an organic light-emitting display device, the sealing process that isolates the organic light-emitting device from the outside is generally performed in order to prevent the penetration of moisture. The conventional sealing methods include a method that laminates an organic thin film and an organic polymer, such as polyester (PET), on the second electrode of an organic light-emitting display device and a method that forms a moisture absorbent in an encapsulating substrate, charges nitrogen gas into the encapsulating substrate, and seals the edge of the encapsulating substrate with a sealant, such as epoxy.

However, because these methods have failed to prevent 100% of the degrading factors such as moisture and oxygen from penetrating from the outside, and these methods are also very complicated to implement, they could not be applied without modifications to organic light-emitting display devices that are very vulnerable to moisture. To solve such problems, a substrate-sealing method that enhances the

adhesiveness between the organic light-emitting device substrate and the encapsulating substrate by using a sealant, such as frit, has been developed.

By using a structure in which the organic light-emitting display device is sealed with frit coated on a glass substrate, the space between the organic light-emitting device substrate and the encapsulating substrate is fully sealed, and thus the organic light-emitting display device can be protected more effectively.

In this method of sealing the substrate with a sealant such as frit, the frit is coated on the sealing part of the organic light-emitting display device, and a laser beam irradiation apparatus irradiates a laser beam on the sealing part of the organic light-emitting display device in motion to harden the frit, thereby sealing the substrate.

SUMMARY OF THE INVENTION

Exemplary embodiments of the present invention provide a laser beam irradiation apparatus for conveying desired laser intensity locally to the sealing part, and a method of manufacturing an organic light-emitting display device by using the same.

According to one exemplary embodiment of the present invention, there is provided a laser beam irradiation apparatus including: a laser source configured to emit light; a collimator configured to collimate the emitted light; a scanner configured to adjust the collimated light to change an irradiation direction thereof; a first lens part configured to focus the adjusted light to irradiate a laser beam on a sealing part; a camera configured to receive visible light passing through the scanner; a heat sensing part configured to receive infrared (IR) light passing through the scanner; and a control part configured to control a moving direction and an intensity of the laser beam.

According to one exemplary embodiment, there is provided a laser beam irradiation apparatus including: a laser source to emit light; a collimator configured to collimate the emitted light; a scanner configured to adjust the collimated light to change an irradiation direction thereof; a first dichroic mirror configured to reflect the adjusted light; a first lens part configured to focus the reflected light to irradiate a laser beam on a sealing part; a camera configured to receive visible light that is incident on the first lens part and passes through the first dichroic mirror; a heat sensing part configured to receive infrared (IR) light that is incident on the first lens part and passes through the first dichroic mirror; and a control part configured to control a moving direction and an intensity of the laser beam.

According to one exemplary embodiment, there is provided a method of manufacturing an organic light-emitting display device using a laser beam irradiation apparatus, including: forming an organic light-emitting part; forming a sealing part around the organic light-emitting part, the sealing part being formed on a first substrate or a second substrate; aligning the first substrate and the second substrate; and irradiating a laser beam such that the laser beam moves along the sealing part while performing a rotation motion, and an intensity of the laser beam is changed when the laser beam is performing the rotation motion.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features and advantages of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings.

FIG. 1 is a schematic view illustrating a method of sealing a sealing part of an organic light-emitting display device by using a laser beam irradiation apparatus according to one exemplary embodiment. FIG. 1 is a cross-sectional view of part of the laser beam irradiation apparatus and the organic light-emitting display device.

FIG. 2 is a top view of part of the laser beam irradiation apparatus and the organic light-emitting display device shown in FIG. 1.

FIG. 3 is a view schematically illustrating a laser beam irradiation apparatus according to one exemplary embodiment.

FIG. 4 is a view schematically illustrating a laser beam irradiation apparatus according to one exemplary embodiment.

FIG. 5 is a view illustrating a motion path of a laser beam according to one exemplary embodiment.

FIG. 6 is a view illustrating a rotation motion and rectilinear motion of a laser beam according to one exemplary embodiment.

FIG. 7 is a view illustrating an intensity change of a laser beam in the rotation motion of the laser beam according to one exemplary embodiment.

DETAILED DESCRIPTION OF ILLUSTRATED EMBODIMENTS

Hereinafter, exemplary embodiments of the present invention will be described in more detail with reference to the accompanying drawings. The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention, and together with the description serve to explain the principles of the invention.

In the drawings, the thickness of layers, films, panels, regions, etc. may be exaggerated for clarity. Like reference numerals designate like elements throughout the specification. It will be understood that when an element such as a layer, film, region, or substrate is referred to as being “on” another element, it can be directly on the other element or intervening elements may also be present. In contrast, when an element is referred to as being “directly on” another element, there are no intervening elements present. It will be understood that for the purposes of this disclosure, “at least one of X, Y, and Z” can be construed as X only, Y only, Z only, or any combination of two or more items X, Y, and Z (e.g., XYZ, XYY, YZ, ZZ).

FIG. 1 is a schematic view illustrating a method of sealing a sealing part 40 of an organic light-emitting display device 1000 by using laser beam irradiation apparatuses 1 and 2 according to one exemplary embodiment. FIG. 1 is a cross-sectional view of part of the organic light-emitting display device 1000 and the laser beam irradiation apparatuses 1 and 2. FIG. 2 is a top view of part of the organic light-emitting display device 1000 and the laser beam irradiation apparatuses 1 and 2 shown in FIG. 1.

Referring to FIGS. 1 and 2, an organic light-emitting part 30 and the sealing part 40 surrounding the organic light-emitting part 30 are disposed between a first substrate 10 and a second substrate 20, and a laser beam 60, which may be

emitted from the laser beam irradiation apparatus 1 and/or 2, is irradiated on the sealing part 40.

In accordance with one exemplary embodiment, the organic light-emitting part 30 is formed on the first substrate 10. The first substrate 10 may be a substrate suitable to support the overlying structure. The first substrate 10 may include a flexible material, a glass substrate, a quartz substrate, and the like. For instance, the first substrate may be formed of glass.

In accordance with one exemplary embodiment, the second substrate 20 is an encapsulating substrate that encapsulates the organic light-emitting part 30 formed on the first substrate 10 and may include a substrate through which the laser beam 60 passes, as will be described below. The second substrate 20 may include a flexible material, a glass substrate, a quartz substrate, and the like. For instance, the second substrate 20 may be formed of glass.

Further, the organic light-emitting part 30 may include one or more organic light-emitting devices (OLEDs) (not shown) in which one or more organic layers (not shown), including an emitting layer between a first electrode (not shown) and a second electrode (not shown), are provided. Here, the first electrode (not shown) may act as an anode into which holes are supplied, and the second electrode (not shown) may act as a cathode into which electrons are supplied.

The OLEDs (not shown) may be categorized into the passive matrix type and the active matrix type depending on whether the driving of the OLEDs is controlled using a thin film transistor (TFT). Exemplary embodiments of the present disclosure may be applied to both the passive matrix and the active matrix types.

In accordance with one exemplary embodiment, the sealing part 40 may be formed on the second substrate 20 adjacent the above-described organic light-emitting part 30. For instance, the sealing part 40 may be formed on the second substrate 20 to surround the organic light-emitting part 30.

The sealing part 40 may form a closed loop for preventing contact between the organic light-emitting part 30 and external moisture or oxygen.

FIGS. 1 and 2 show that each of the corners of the sealing part 40 forming the closed loop is formed in the shape of a curve having a certain curvature. However, exemplary embodiments of the subject matter are not limited thereto. For instance, each corner of the sealing part 40 may form substantially an orthogonal shape with no or little curvature.

In accordance with one exemplary embodiment, a suitable sealant may be used as the sealing part 40 to secure the sealability between the first substrate 10 and the second substrate 20 and protect the organic light-emitting part 30 more effectively. The sealant may be formed to have a certain width FW by various methods, such as a screen printing method or a pen dispensing method. The sealant may be organic and/or inorganic materials. For instance, the sealant may be frit.

In accordance with one exemplary embodiment, after the sealing part 40 is formed on the second substrate 20, and the organic light-emitting part 30 is formed on the first substrate 10, the first substrate 10 and the second substrate 20 may be aligned with each other. However, exemplary embodiments of the subject matter are not limited thereto. For example, after the sealing part 40 may be formed on the first substrate 10 with the organic light-emitting part 30 formed thereon, the first substrate 10 may be aligned with and coupled to the second substrate 20.

Moreover, although it is illustrated in the drawing that one organic light-emitting part **30** is provided, one of ordinary skill in the art will appreciate that a plurality of organic light-emitting parts **30** and a plurality of sealing parts **40** respectively surrounding the plurality of organic light-emitting parts **30** may be provided between the first substrate **10** and the second substrate **20**.

The laser beam irradiation apparatuses **1** and **2** may irradiate the laser beam **60** along a path of the sealing part **40** disposed between the first substrate **10** and the second substrate **20**. The laser beam **60** may be irradiated on the sealing part **40** in the form of spot beams having a flat top profile.

In accordance with one exemplary embodiment, the first substrate **10** may be mounted on substrate stage **70** so that the substrate stage **70** is under the first substrate **10**. The position of the laser beam **60** irradiated on the sealing part **40** may be relatively moved by moving the substrate stage **70**. Alternatively/additionally, the position of the laser beam **60** may be moved by the motion of the laser beam irradiation apparatuses **1** and **2**.

FIG. 3 is a view schematically illustrating the laser beam irradiation apparatus **1** according to one exemplary embodiment.

Referring to FIG. 3, the laser beam irradiation apparatus **1** according to one exemplary embodiment may include a laser source **110**, a scanner **120**, a first lens part **130**, a camera **140**, a heat sensing part **150**, a control part **160**, an illumination part **170**, a first dichroic mirror **181**, and a second dichroic mirror **182**.

The laser source **110** may generate laser light. In accordance with one embodiment, laser light having a wavelength of 808 nm may be emitted from the laser source **110**.

A collimator **115** may be connected to the output of the laser source **110**. The collimator **115** changes the light emitted from the laser source **110** to collimated light **191**. The collimator **115** may have a focal distance of 50 nm.

The scanner **120** may be disposed on the path of collimated light **191** from the collimator **115**. The collimated light **191** from the collimator **115** may be reflected to the scanner **120** by the first dichroic mirror **181**.

The scanner **120** may include a reflective part (not shown), which reflects the collimated light **191** from the collimator **115** to the sealing part **40**, and a driving part (not shown) that drives the reflective part. A portion of the reflective part (not shown) may use a galvanometer mirror that precisely controls the position and speed of a laser beam, for instance, for the rotation motion of the laser beam **60** according to one exemplary embodiment. The galvanometer mirror may have a high reflectivity at a wavelength band of 450 nm to 2,600 nm.

In accordance with one exemplary embodiment, the first lens part **130** may be disposed on the path of light passing through the scanner **120**. The light passing through the scanner **120** may be collected by the first lens part **130**. The first lens part **130** may include an F-theta lens. The F-theta lens may have a focal distance of 80 nm.

In accordance with one exemplary embodiment, the light of all wavelengths reflected by the sealing part **40** passes back through the scanner **120**.

For instance, the visible light **193** reflected by the sealing part **40** is incident on the camera **140**. Thus, visual information relating to the sealing operation may be provided by the camera **140** simultaneously with the operation. In accordance with one exemplary embodiment, the camera **140** may be a charged coupled device (CCD) camera.

A focusing lens **143** may be coupled to the camera **140**. The focusing lens **143** may be used for adjusting the magnification of the image fed to the camera **140**. For instance, the focusing lens **143** may have a focal distance of 80 nm. A bandpass filter **146** may be coupled to the focusing lens **143**. The bandpass filter **146** may be a filter that passes only the light of a wavelength band of 532 nm to 615 nm.

In accordance with one exemplary embodiment, the infrared (IR) light **194** reflected by the sealing part **40** is incident on the heat sensing part **150**. Thus, thermal information relating to the sealing operation may be provided by the heat sensing part **150** simultaneously with the sealing operation. The heat sensing part **150** may be, for instance, a pyrometer or an IR camera.

A focusing lens **153** may be coupled to the heat sensing part **150**. The focusing lens **153** may have a focal distance of 40 nm or 80 nm. An IR blocking filter silicon **156** may be coupled to the focusing lens **153**. The IR blocking filter silicon **156** can prevent IR light from being leaked to the outside.

In accordance with one exemplary embodiment, the control part **160** controls the moving direction and intensity of the laser beam **60**. The control part **160** may include a program for controlling a galvanometer mirror (not shown), which controls the position and speed of the laser beam **60** in order for the laser beam **60** to have varying intensity and rotational moves, and a laser driver that changes the intensity of the laser beam **60** in each segment of the rotation motion of the laser beam **60**.

In accordance with one exemplary embodiment, the illumination part **170** may irradiate light on the sealing part **40** to illuminate the periphery of the sealing part **40**. The illumination part **170** may use a light-emitting diode (LED), and have a wavelength of 532 nm to avoid overlapping with the wavelength band of the laser beam **60**, the visible light band to be used for real-time measurement, and the IR band to be used for real-time measurement.

The first dichroic mirror **181** may be disposed on the path of light passing through the collimator **115** and the path of light of all wavelengths which is reflected by the sealing part **40** and passes back through the scanner **120**. The first dichroic mirror **181** may have a high reflectivity at the wavelength of light passing through the collimator **115**, and may have a high transmittance at the visible light wavelength band and the IR wavelength band. For instance, the first dichroic mirror **181** may have a high reflectivity at a wavelength band of 808 nm, and may have a high transmittance at a wavelength band of 532 nm to 615 nm and 1.5 μm to 2.3 μm . Therefore, light from the laser source **110** and the collimator **115** is reflected by the first dichroic mirror **181**, and is incident on the scanner **120**. Among the light of all wavelengths which is reflected by the sealing part **40** and passes back through the scanner **120**, light **192** having the same wavelength band as that of the light from the laser source **110** and the collimator **115** is filtered by the first dichroic mirror **181**. Among the light of all wavelengths which is reflected by the sealing part **40** and passes back through the scanner **120**, the visible light **193** and the IR light **194** pass through the first dichroic mirror **181**.

The second dichroic mirror **182** may be disposed on the path of light passing through the first dichroic mirror **181**. The second dichroic mirror **182** may have a high reflectivity at the wavelength band of visible light, and may have a high transmittance at the IR wavelength band. For instance, the second dichroic mirror **182** may have a high reflectivity at a wavelength band of 532 nm to 615 nm, and may have a high transmittance at a wavelength band of 1.5 μm to 2.3 μm .

Therefore, the visible light **193** is reflected by the second dichroic mirror **182** and is incident on the camera **140**, and the IR light **194** passes through the second dichroic mirror **182** and is incident on the heat sensing part **150**. Thus, visual information may be provided by the camera **140** simultaneously with the sealing operation, while thermal information may be provided by the heat sensing part **150** simultaneously with the sealing operation.

Light emitted from the laser source **110** is changed to the collimated light **191** by the collimator **115**, reflected by the first dichroic mirror **181**, and incident on the scanner **120**. The direction of the light incident on the scanner **120** may be changed by the scanner **120**, and thus the laser beam **60** may be irradiated on the sealing part **40**.

Among the light of all wavelengths reflected by the sealing part **40**, light having the same wavelength band as that of the light emitted from the laser source **110** is changed in directions by the scanner **120**, and filtered by the first dichroic mirror **181**. Among the light of all wavelengths reflected by the sealing part **40**, the visible light **193** is changed in directions by the scanner **120**, passes through the first dichroic mirror **181**, is reflected by the second dichroic mirror **182**, and is irradiated onto the camera **140**. Among the light of all wavelengths reflected by the sealing part **40**, the IR light **194** is changed in directions by the scanner **120**, passes through the first dichroic mirror **181** and the second dichroic mirror **182**, and is irradiated onto the heat sensing part **150**.

FIG. 4 is a view schematically illustrating the laser beam irradiation apparatus **2** according to one exemplary embodiment.

Referring to FIG. 4, the laser beam irradiation apparatus **2** according to one exemplary embodiment may include a laser source **210**, a scanner **220**, a second lens part **230**, a camera **240**, a heat sensing part **250**, a control part **260**, an illumination part **270**, a third dichroic mirror **281**, a fourth dichroic mirror **282**, and a fifth dichroic mirror **283**.

The laser source **210** may generate laser light. For instance, laser light having a wavelength of 808 nm may be emitted from the laser source **210**.

A collimator **215** may be connected to the output of the laser source **210**. The collimator **215** changes the light emitted from the laser source **210** to collimated light **291**. The collimator **215** may have a focal distance of 30 nm.

The scanner **220** may be disposed on the path of the collimated light **291** from the collimator **215**. The collimated light **291** from the collimator **215** may be directly incident on the scanner **220**.

The scanner **220** may include a reflective part (not shown), which reflects the collimated light **291** from the collimator **215** to the sealing part **40**, and a driving part (not shown) that drives the reflective part. A portion of the reflective part (not shown) may use a galvanometer mirror that precisely controls the position and speed of a laser beam for the rotation motion of the laser beam **60** according to one exemplary embodiment. The galvanometer mirror may have a high reflectivity at a wavelength band of 808 nm.

In accordance with one exemplary embodiment, the second lens part **230** may be disposed on the path of light **292** passing through the scanner **220**. The light **292** passing through the scanner **220** may be reflected by the third dichroic mirror **281** and irradiated on the second lens part **230**. The light **292** passing through the scanner **220** may be collected by the second lens part **230**. The second lens part **230** may include an F-theta lens. The F-theta lens may have a size of 2" to 3".

In accordance with one exemplary embodiment, the light of all wavelengths reflected by the sealing part **40** passes back through the second lens part **230**.

For instance, the visible light **293** reflected by the sealing part **40** is incident on the camera **240**. Visual information relating to the sealing operation may be provided by the camera **240** simultaneously with the operation. The camera **240** may be a CCD camera.

A focusing lens **243** may be coupled to the camera **240**. The focusing lens **243** may be used for adjusting the magnification of the image fed to the camera **240**. The focusing lens **243** may have a focal distance of 100 nm. A bandpass filter **246** may be coupled to the focusing lens **243**. The bandpass filter **246** may be a filter that passes only the light of a wavelength band of 525 nm.

In accordance with one exemplary embodiment, the IR light **294** reflected by the sealing part **40** is incident on the heat sensing part **250**. Thermal information relating to the sealing operation may be provided by the heat sensing part **250** simultaneously with the operation. The heat sensing part **250** may be a pyrometer or an IR camera.

An IR blocking filter **256** may be coupled to the heat sensing part **250**. The blocking filter **256** can shut off light having the same wavelength as the light of the laser source **210**. The IR blocking filter **256** may shut off light having a wavelength of 808 nm, and thus only IR light may reach the heat sensing part **150**.

In accordance with one exemplary embodiment, the control part **260** controls the moving direction and intensity of the laser beam **60**. The control part **260** may include a program for controlling a galvanometer mirror (not shown), which controls the position and speed of the laser beam **60** in order for the laser beam **60** to have varying intensity and rotational moves, and a laser driver that changes the intensity of the laser beam **60** in each segment of the rotation motion of the laser beam **60**.

In accordance with one exemplary embodiment, the illumination part **270** irradiates light on the sealing part **40** to illuminate the periphery of the sealing part **40**. The illumination part **270** may use an LED, and have a wavelength of 532 nm to avoid overlapping with the wavelength band of the laser beam **60**, a visible light band to be used for real-time measurement, and an IR band to be used for real-time measurement.

The third dichroic mirror **281** may be disposed on the path of the light **292** passing through the scanner **220** and the path of light of all wavelengths which is reflected by the sealing part **40** and passes back through the second lens part **230**. The third dichroic mirror **281** may have a high reflectivity at the wavelength band of the laser source **210**, and may have a high transmittance at the visible light wavelength band and the IR wavelength band. For instance, the third dichroic mirror **281** may have a high reflectivity at a wavelength band of 808 nm, and may have a high transmittance at a wavelength band of 532 nm and 1,000 nm to 7,000 nm. Therefore, light from the scanner **220** is reflected by the third dichroic mirror **281**, and is incident on the second lens part **230**. Among the light of all wavelengths which is reflected by the sealing part **40** and passes back through the second lens part **230**, light **292** having the same wavelength band as that of the light from the laser source **210** and the collimator **215** is filtered by the third dichroic mirror **281**. Among the light of all wavelengths which is reflected by the sealing part **40** and passes back through the second lens part **230**, the visible light **293** and the IR light **294** pass through the third dichroic mirror **281**.

The fourth dichroic mirror **282** may be disposed on the path of light passing through the third dichroic mirror **281**. The fourth dichroic mirror **282** may have a high reflectivity at the wavelength band of visible light, and may have a high transmittance at the IR wavelength band. For instance, the fourth dichroic mirror **282** may have a high reflectivity at a wavelength band of 525 nm, and may have a high transmittance at a wavelength band of 1,000 nm to 7,000 nm. Therefore, the visible light **293** is reflected by the fourth dichroic mirror **282**, and the IR light **294** passes through the fourth dichroic mirror **282** and is incident on the heat sensing part **250**. Thus, thermal information relating to the sealing operation may be provided by the heat sensing part **250** simultaneously with the operation.

The fifth dichroic mirror **283** may be disposed on the path of light reflected by the fourth dichroic mirror **282**. The fifth dichroic mirror **283** may have a high reflectivity at the wavelength band of visible light. For instance, the fifth dichroic mirror **283** may have a high reflectivity at a wavelength band of 525 nm. Therefore, the visible light **293** is reflected by the fifth dichroic mirror **283**, and is incident on the camera **240**. Thus, visual information relating to the sealing operation may be provided by the camera **240** simultaneously with the operation.

Light emitted from the laser source **210** is changed to the collimated light **291** by the collimator **115**, and is incident on the scanner **220**. The direction of the light incident on the scanner **220** may be changed by the scanner **220**, and the light **292** passing through the scanner **220** is reflected by the third dichroic mirror **281**. Light reflected by the third dichroic mirror **281** may be collected by the second lens part **230**, and thus the laser beam **60** may be irradiated on the sealing part **40**.

Among the light of all wavelengths reflected by the sealing part **40**, light having the same wavelength band as that of the light emitted from the laser source **210** passes through the second lens part **230**, and is filtered by the third dichroic mirror **281**. Among the light of all wavelengths reflected by the sealing part **40**, the visible light **293** passes through the second lens part **230** and the third dichroic mirror **281**, is reflected by the fourth dichroic mirror **282** and the fifth dichroic mirror **283**, and is irradiated onto the camera **240**. Among the light of all wavelengths reflected by the sealing part **40**, the IR light **294** sequentially passes through the second lens part **230**, the third dichroic mirror **281**, and the fourth dichroic mirror **282**, and is irradiated onto the heat sensing part **250**.

FIG. 5 is a view illustrating a motion path P of the laser beam **60**, according to one exemplary embodiment. FIG. 6 is a view illustrating a rotation motion R and rectilinear motion T of the laser beam **60**, according to one exemplary embodiment. FIG. 7 is a view illustrating the intensity change of the laser beam **60** in the rotation motion R of the laser beam **60**, according to one exemplary embodiment.

Referring to FIGS. 5 and 6, the laser beam **60** according to one exemplary embodiment has the motion path P in which the rotation motion R and the rectilinear motion T are combined, and slowly moves along a sealing path of the sealing part **40**. As illustrated, the motion path P of the laser beam **40** may be designed to have, for instance, circular trajectories that may appropriately overlap each other. That is, the circular trajectories may be intended to appropriately overlap each other so that optimal energy is transferred to the frit to thus seal effectively. The laser beam **60** may perform the rotation motion R with a certain rotation radius r_0 . The laser beam **60** may be irradiated in the form of spot beams having a flat top profile. Referring to FIG. 6, the laser

beam **60** in the form of a spot beam performs the rotation motion R around an axis with the rotation radius r_0 . When the center point of the spot beam makes one round to come back to the original point, the laser beam **60** may complete one cycle (or one period) of the rotation motion R according to one exemplary embodiment.

The rotation motion R of the laser beam **60** may be performed by the scanners **120** and **220** and the control parts **160** and **260**. The laser beam irradiation apparatuses **1** and **2** may be moved by a linear motor, and thus the laser beam **60** may perform the rectilinear motion T. Also, the substrate stage **70** under the sealing part **40** moves, and thus the laser beam **60** may perform the rectilinear motion T.

In order to enable desired beam morphing, the cross-sectional diameter of the laser beam **60** should have a sufficient magnitude, but may be less than the width FW of the sealing part **40**. Specifically, the diameter of the spot beam may be $\frac{1}{4}$ to $\frac{3}{4}$ times the frit width.

Further, in accordance with one exemplary embodiment, in performing the rotation motion R of the spot beam, the spot beam in substantially circular shape may be rotated so that its circular trajectory does not overlap during one cycle of rotation. Therefore, the minimum rotation radius of the spot beam may be decided to be the smallest rotation radius with which the circular trajectory of the spot beam does not overlap during one cycle of rotation. Therefore, the minimum rotation radius may be the radius of the spot beam. For example, when the diameter of the spot beam is 1.3 mm, the minimum rotation radius of the rotation motion R of the spot beam is 0.65 mm. For example, when the diameter of the spot beam is 1.3 mm, and the rotation radius r_0 of the rotation motion R of the spot beam is 1.3 mm, the diameter of the outermost circle based on the rotation motion R of the spot beam is 3.9 mm.

The laser beam **60** may circularly perform the rotation motion R at a speed faster than the rectilinear motion T. When the frit width is 100 mm, the rotation frequency of the rotation motion R of the spot beam may be 50 Hz or higher. For instance, the rotation frequency may be in a range of 40-60 Hz. The laser beam **60** circularly performs the rotation motion R at a high speed, and thus desired beam morphing is possible.

Referring to FIG. 7, when the laser beam **60** is performing the rotation motion R, the intensity of the laser beam **60** may be changed.

The laser beam **60** has the motion path P in which the rotation motion R and the rectilinear motion T are combined, and the intensity of the laser beam **60** is changed in each segment of the rotation motion R. Therefore, desired beam morphing is possible, and desired varying laser intensity may be transferred to the frit.

In accordance with one exemplary embodiment, the circumference of the path of the rotation motion R is divided into a plurality of segments at certain angles α , and the segments may have different laser intensities. Such variation may be supported by the laser drivers of the control parts **160** and **260**. According to one exemplary embodiment, the circumference of the path of the rotation motion R may be divided at intervals of 45 degrees. Therefore, the circumference of the path of the rotation motion R may be divided into a first segment **S1**, a second segment **S2**, a third segment **S3**, a fourth segment **S4**, a fifth segment **S5**, a sixth segment **S6**, a seventh segment **S7**, and an eighth segment **S8**. The first segment **S1** has a first laser beam intensity, the second segment **S2** has a second laser beam intensity, the third segment **S3** has a third laser beam intensity, the fourth segment **S4** has a fourth laser beam intensity, the fifth

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segment S5 has a fifth laser beam intensity, the sixth segment S6 has a sixth laser beam intensity, the seventh segment S7 has a seventh laser beam intensity, and the eighth segment S8 has an eighth laser beam intensity.

The laser beam 60 has the motion path P in which the rotation motion R and the rectilinear motion T are combined, the circumference of the path of the rotation motion R is divided into the eight segments having different intensities, and the intensities of eight segments are controlled, and thus a desired beam profile is realized. Therefore, in a segment in which the type of the lower layer of the frit is locally changed or its geometry is changed, the beam profile may be momentarily adjusted according to the change, thus preventing damage to local wiring or the like. Also, the laser intensity inside the corner of the frit should be reduced by about half of the laser intensity outside the corner, and since the beam profile can be adjusted at the corner, sealing quality outside and inside the corner can be maintained uniform.

According to exemplary embodiments of the present invention, a high-quality frit sealing process can be performed without thermal damage to peripheral elements.

While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the following claims.

What is claimed is:

1. A laser beam irradiation apparatus comprising:
 - a laser source configured to emit light;
 - a collimator configured to collimate the emitted light;
 - a scanner configured to adjust the collimated light to change an irradiation direction thereof;
 - a first lens part configured to focus the adjusted light to irradiate a laser beam on a sealing part;
 - a camera configured to receive visible light passing through the scanner;
 - a heat sensing part configured to receive infrared (IR) light passing through the scanner; and
 - a control part configured to control a moving direction and an intensity of the laser beam,
 wherein:

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the moving direction follows a rotation motion; the circumference of a path of the rotation motion is divided into a plurality of segments, each segment subtending the same angle of the rotation motion; and the control part comprises a laser driver and is configured to vary an amount of power applied to produce the laser beam by the laser source in order to vary the intensity of the laser beam to be different in each of the plurality of segments independently of the motion of the laser beam.

2. The laser beam irradiation apparatus of claim 1, further comprising a dichroic mirror configured to reflect the collimated light from the collimator to the scanner and to filter light that has the same wavelength as laser light and is incident on the scanner.

3. The laser beam irradiation apparatus of claim 1, further comprising a dichroic mirror configured to reflect the visible light onto the camera and to pass the IR light onto the heat sensing part.

4. The laser beam irradiation apparatus of claim 1, further comprising an illumination part configured to irradiate illumination light on the sealing part.

5. The laser beam irradiation apparatus of claim 1, wherein the control part is further configured to cause the laser beam to move along a first direction while performing the rotation motion.

6. The laser beam irradiation apparatus of claim 5, wherein a frequency of the rotation motion is in a range of 50-60 Hz.

7. The laser beam irradiation apparatus of claim 5, wherein the control part is further configured to cause the rotation motion of the laser beam such that the laser beam forms a trajectory that does not overlap during one period of the rotation motion.

8. The laser beam irradiation apparatus of claim 5, wherein:

- the scanner comprises a galvanometer mirror configured to enable the rotation motion; and
- the control part further comprises a program configured to control the galvanometer mirror.

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